Comment on "Lack of Destructive Interference of Landau Edge States in the Quantum Hall Regime"

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In a recent Letter [1], J.E. Müller presents a model calculation which demonstrates explicitly the absence of destructive quantum interference between edge states at the same sample edge in the QHE-regime. Basically the lack of destructive interference can be concluded from absence of back scattering within the same edge. Although the absence of back scattering is well known for a long time, a microscopic picture on the basis of phase coherent electron waves in multiply connected edge channel (EC) paths did not exist before. The intention of Müllers paper therefore was to present a model calculation which allows to understand how the quantum interference between ECs manages to avoids the need of back scattering.

The intention of this comment is to bring up some more general aspects which should also be discussed in context with this model. The most critical point in the presented model calculation seems to be the choice of the initial situation. In the calculation of Müller the initial state of the electron was prepared in a way that it is localized already in the incoming lead before the EC is split up into two phase coherent alternative paths. If the electron is already "on the way" to the dot, it is clear that there is no other way for the electron than being transmitted fully through the edge channel and the describing wavefunction has to account for this as demonstrated. Fig.1 shows a general situation of a quantum interference experiment:

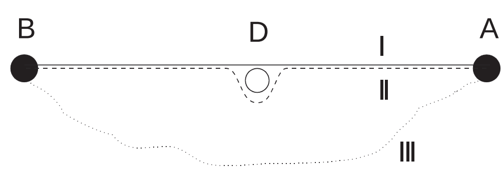

FIG. 1. Scheme of phase coherent transport including a barrier (D) which splits up the path into two phase coherent parts. The resulting two possibilities for transmission from A to B are represented by path I and II. Path III represents some alternative not particularly known paths in a real structure.

Suppose there is an EC transmitting from (contact) A to B. It is split into two phase coherent parts at dot D. If the EC transport is phase coherent, it should be possible to describe the situation also by superposition of the following two phase coherent paths: (I) The electron leaving at A arrives at B without being displaced at D or (II) the electron leaving at A is displaced at D and arrives also at B. A realistic case should provide also an alternative path (labeled III) which accounts for other ECs or the possibility of being scattered to some probably present non-localized states in the bulk region of a real sample. In general the phase coherent transport does not allow to "watch" the electron without destroying the phase. All what can be done in an experiment is therefore to observe an electron leaving at A and arriving at B without knowing the exact way. Since the knowledge of the initial position of the electron implies a phase destroying event, a realistic initial location for the electron would be a place "outside" the phase coherent region at point A. But starting at A one can no longer be sure that the electron really enters the paths I or II because it has also the choice of entering III. Consequently there is only left a probability for the electron entering I, II or entering III. If the electron starts at A, there comes up another most important aspect which has not been considered so far: If paths I and II are assumed to result from an EC running from A to B, the transmission must include also the EC of the opposite sample edge. For calculating a transmission probability between A and B definitely the ECs at both edges are needed [2]. Since the topic of the Letter [1] is clearly directed to the question what is going on within one particular edge, there is no basis for discussing any observable effects like transmission between the contacts or quantum interference. Therefore a comparison with the general aspects of a quantum interference experiment like in Fig.1 must fail. This apparent discrepancy is probably connected to the frequently raised argument that considering EC-transport like a current in a real channel is perhaps not the whole truth of the physics behind. One point may be that the permanently propagating electrons along the edge have to be replaced by quantum mechanically well defined Eigenstates. An Eigenstate which is extended over the whole sample does not "need" interference because it has all information about the whole sample and therefore it "knows" how to arrange the associated wave function in order to maintain the associated (virtual) persistent edge current. On this background the results of Müller are even more important because he demonstrates explicitly that even in the presence of disorder the wavefunction of an edge electron is able to adjust itself in order to maintain the well defined macroscopic behavior of edge states. But it seems to be some how missleading to characterize this effect to be a consequence of quantum interference.

[1] J.E. Müller, Phys. Rev. Lett. 72 (16), 2616 (1994)
[2] M. Büttiker, Phys. Rev. B 38, 9375 (1988)